Descriptive Study on Rehabilitation Treatment Methods for Improving Upper Limb Function in Stroke Patients

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Abstract

Stroke is a central nervous system disease that causes partial loss of brain function due to the sudden hematopoietic or bleeding of the brain's blood supply to the brain tissue. Currently, therapeutic interventions for stroke patients include nerve system therapy, Bobath therapy, PNF, task-oriented training, CIMT, mirror therapy, and imagination training as various ways to improve upper limb function. In addition, research on robot therapy for continuous upper extremity training programs has been actively conducted, and recently, treatments using virtual reality systems have been introduced. However, despite the introduction of several treatments, most therapists tend to stick to only the methods they have largely treated. If the therapist can accurately recognize each treatment method and apply the appropriate treatment method to various situations, a more qualitative treatment can be applied. Therefore, this study investigates treatments for improving the function of the upper extremities of stroke patients and seeks to explore the advantages and disadvantages of treatment methods and better use.

Keywords: Stroke, Upper limb rehabilitation, Treatment methods

1. Introduction

Stroke is a disease in the central nervous system in which sudden ischemia or hemorrhage in blood vessels inhibits the smooth blood supply to brain tissues, thereby causing a partial loss of brain function and consequent functional disorders [1]. Stroke patients generally experience neurological disorders, such as motor, sensory, cognitive, language, and emotional disorders [2]. Particularly, patients with stiffening, muscular weakness, excessive tension, and imbalances in their upper limbs can lose the ability to control their upper limb movement and thus perform only limited social activities and Activities of Daily Living (ADLs) [3][4]. These disorders cause stroke patients to experience lowered self-efficacy, psychological and emotional pains (such as depression) and lowered quality of life [5][6]. At least 70% of stroke patients develop upper limb paralysis, and at least 60% show declines in dexterity [6]. Stroke patients most commonly recovered from the disease three to six months after its onset. Rehabilitative treatments during this period can facilitate their functional restoration by aiding

in neurological recovery [7]. Within six months after stroke onset, patients can hardly exercise and thus require the assistance of therapists.

Approximately 85% of stroke patients exhibit cognitive, motor, sensory, and balance disorders, and over 69% of them develop dysfunctions in their affected upper limbs [8]. Notably, according to previous research, only about 20% of patients who showed severe motor disorders in their affected upper limbs in the early stages of stroke partially recover their upper limb function, and less than 5% of these patients fully recover their upper limb function. Moreover, around 25% of stroke patients complain of difficulties in the proper use of their upper limbs even five years after stroke onset, signifying small chances of recovering upper limb function after a stroke [9][10]. Upper limb disorders occurring after a stroke become a primary cause of the inhibition of movements such as eating, walking, handwriting, balancing, manipulation, delicate hand movements, personal hygiene management, and expression of opinions; thus, these disorders hinder stroke patients' social independence and degrade their quality of life [11]. Stroke patients' recovery of their upper limb function is important for them to maintain the most basic human life. This function may be as crucial for performing ADLs as the lower limb's gait function [12].

The reason for focusing on upper limb rehabilitation out of the various issues that stroke patients can experience is that impairment of the middle cerebral artery, which is in charge of upper limb function, accounts for 75% of all stroke cases [13]. A stroke patient's weakness in the upper limb increases his/her reliance on others by lowering their independence in performing ADLs. Particularly, a patient whose weakened upper limb and major hand are on the same side needs assistance in most ADLs, including eating, face washing, toilet use, dressing, and grooming. Therefore, not only stroke patients but also their caregivers, who should stay close to them, can experience declines in their quality of life. Stroke patients' upper limb rehabilitation should aim to reduce the spread of brain damage during the acute treatment period and mitigate the disorders resulting from aftereffects through the problem-solving process after the acute stage [13][14].

At present, stroke interventions employ various methods to improve upper limb function, including Bobath therapy, Proprioceptive Neuromuscular Facilitation (PNF), and task-oriented training. In addition, interventions and studies are underway for upper limb training programs, such as Constraint-Induced Movement Therapy (CIMT), and mirror therapy. In recent years, treatments using the robot and virtual reality systems have also been adopted [15].

However, despite the wide range of treatment and evaluation methods introduced to date, many therapists cling to the methods that they have mainly been using. If the therapist can accurately recognize each treatment method and apply the appropriate treatment method to various situations, a more qualitative treatment can be applied. Therefore, this study intends to introduce the existing treatment and evaluation methods for improving stroke patients' upper limb function and find ways for therapists to make better use of them through a proper understanding of each method's characteristics.

2. Methods

This study found and compiled papers on Bobath therapy, PNF therapy, Task-oriented movement therapy, CIMT, and Mirror therapy among the upper limb rehabilitation methods of stroke patients posted on Pub-Med since 2000.

2.1. Bobath therapy

The general purpose of Bobath therapy is to establish treatment programs that enable an individual to withstand the pressure from repeated active exercises, gravity, weight, or hands; achieve a balance between muscle groups; and reduce the effects of abnormal tension in exercise patterns and autonomous responses [16].

The principle of Bobath therapy is to inhibit abnormal types of sensory stimulations in the sensorimotor system's abnormal closed loops, arouse normal sensory stimulations as much as possible, and facilitate the maximum level of normal sensory inputs, thereby preventing the vicious cycle of abnormally closed loops. To activate this inhibition, reflex inhibitory postures were developed [16]. Bobath therapy addresses the particular problem where abnormal and widespread reflex patterns of exercises and postures occur from the brain stem, cerebellum, midbrain, basal ganglia, and cortex through their disassociation from inhibition. Therefore, this therapy is based on an approach to normal development, motion compensation, and habitual exercise patterns that can cause muscular imbalances or contractions. The underlying concepts of Bobath therapy are autonomous postural adaptation, sensory structures for inducing postural responses, muscle tone, fixation aimed at compensating for low muscle tone, development of motility, cognition of kinetic potentials, development of active muscles, and supply of muscle control [16]. Bobath therapy uses functional activities and teaches how to process muscle tensions. It values the quality of movements in every activity, encourages patients to perform on their own as much as possible, and emphasizes early treatment. It even teaches patients with cerebrovascular diseases to maintain proper postures in bed to enable them to recognize and use their affected sides. It also trains patients in skills to move quickly in bed as early as possible to help them avoid movement patterns that strengthen abnormal reflexes. Therapists should control patients' movements to generate normal patterns and teach them to sense such movements. Patients are also instructed to reduce the number of movements controlled by therapists and replace therapists' control with their own. Key points of control are used to promote normal movements. Initially, key points of control are mostly in the body's proximal parts, such as the trunk and the pelvis. As their conditions improve, patients learn to use the distal parts of their bodies as the core of control. Therapists should control the intensity of therapy to promote patients' control of their movements [17].

2.2. Proprioceptive Neuromuscular Facilitation (PNF)

PNF treatment aims to increase the potential memory of movement patterns that are as normal as possible in the central nervous system. This is achieved by providing a sufficient level of early aids (proprioceptive, foreign, and terminal-receptive signals) to arouse patients' needs and responses. Self-reliance means patients' deferred tasks for future use and already learned tasks [16].

PNF involves spiral and diagonal mass movement patterns [18]. These patterns are a combination of exercises in the sagittal, coronal, and cross-sectional planes. Specifically, PNF combines flexion and extension in the sagittal plane, pronation and supination in the coronal plane, and rotation in the cross-sectional plane. This combination of functional movements increases muscle activities and spreads them toward the proximal and distal areas [19]. These characteristics can explain Beevor's principle: 1) PNF uses group movement patterns that become the basis of all techniques. 2) Mass muscular movement patterns are the original trait of normal movements. 3) The brain is not aware of any individual muscle action except the movements that occur. Mass movement patterns can be classified as the upper limb, lower

limb, trunk, cephalic, and temporomandibular patterns. These patterns vary by the joint(axis) from which movements mainly occur. When each pattern is clinically used, the combination of rhythmic inception, rhythmic stability, repeated contraction, the timing of emphasis, reversed motions by the antagonist, slow reversal, reversal of the antagonist and the agonist, contraction-relaxation, maintenance-relaxation, and isotonic contraction can result in numerous variations of a single pattern [20].

The locations and positions of patients and therapists, verbal orders for auditory stimulations, use of patients' vision, extension and compression, timing, and movement patterns are applied in methods and procedures of applying the facilitation, proper resistance, use of diffusion and reinforcement, and barehand contact for cognitive and tactile simulations [19].

2.3. Task-oriented movement therapy

In the 1980s, selective task-oriented training was developed as a treatment technique for stroke patients based on motor learning theory. This training assumes that the provision of functional tasks to patients and their active problem-solving are more effective for learning than the repeated training of a single movement [21]. Selective task-oriented training is characterized by its task-oriented approach to motor recovery. It is also based on dynamic system theory, which explains the performance of the tasks and motor recovery that occur in the dynamic interactions between individuals, environments, and tasks that they perform [22].

Stroke patients' selective task-oriented training is goal-oriented; it helps them achieve their goals by performing movements within their daily environments through the provision of functional tasks. It is also an effective treatment technique through which stroke patients can expect functional recoveries [23]. Patients' full engagement in an activity or task from the beginning to the end can elicit stronger, more effective, and coordinated motor responses than partial engagement [24]. Previous research on task-oriented training shows that tasks and intervention strategies that provide meaningful activities related to daily living are more helpful than repeated or passive exercises for learning skills and improving functions [25]. A study on selective task-oriented training reports that task training focused on patients' preferred tasks or goals facilitates changes in ADLs and subsequently produced more effective outcomes from rehabilitation treatments [26].

2.4. Constraint-Induced Movement Therapy (CIMT)

CIMT is a behavioral neuroscience-based treatment method used to enhance a stroke patient's motor performance on the affected side in the field of neurorehabilitation [27]. Stroke patients mostly experience difficulties in using their affected upper limbs and thus learn patterns using their unaffected sides to compensate for such insufficient motions. Continued compensatory learning hinders their intrinsic recovery [28]. Taub et al. (1980) explained this phenomenon using the term "learned nonuse". In their study, they blocked the vision of monkeys on one side and had them wear jackets designed to constrain their motions and suppress their compensatory patterns in the unaffected healthy upper limb; as a result, the monkeys used the affected side. Based on this principle, CIMT was introduced as a treatment that enables the learning of functional movement patterns by limiting the use of the unaffected side and inducing intensive movements on the affected side to control learned nonuse. In recent years, it has further evolved into the concept of task-oriented movement therapy [27].

CIMT is offered to stroke patients to enhance hemiplegic patients' upper limb function by overcoming the learned nonuse that occurs in the acute stage after stroke onset and inducing changes in the cerebral cortex [29].CIMT, which constrains the unaffected side, increases the use of the affected side through continuous and repeated practices of functional arm movements. Recent studies explain this therapy with changes in movement patterns, which are explained through kinetic analyses, and local terminal sprouting or functional synaptic reorganization achieved by stimulating the undamaged cortical circuit and the sensory cortex adjacent to the damaged area [30][31].

2.5. Mirror therapy

Contradicting the basic concept that sensorimotor training is effective for motor skills, mirror therapy is based on the facilitation of the mirror neuron system and induces improvements in the affected side's movements by providing visual information (the unaffected side's movements are reflected in the mirror as if they were the affected side's); mirror therapy focuses on the fact that visual stimulations are effective for improving motor skills [32]. This therapy was introduced by Ramachandran (1994) for phantom pain reduction in amputees. Its effects on reducing pain and stiffening have been reported [33]. Mirror therapy was also adopted by Altschuler, Wisdom, and Stone (1999) as a treatment to restore stroke patients' upper limb function [34]. Moreover, a systematic review by Pollock et al. (2014) defined mirror therapy in the rehabilitation of stroke patients as a visual stimuli-based technique that creates an illusion of movements on the affected side through the mirror reflection of the actual upper and lower limb movements on the unaffected side for the performance of tasks [35]. Mirror therapy positively affects stroke patients' upper limb function and ability to perform ADLs [36].

The neurological mechanism of mirror therapy is highly associated with the superior temporal sulcus, and the activation of the primary motor area is exhibited through magnetic resonance imaging [37].In addition, Thirumala et al. (2002) validated the effects of mirror therapy via mirror neurons by confirming increased stimulations in the primary motor cortex and both inferior parietal lobules during observation of upper limb and hand movements via the mirror [38]. According to a review of previous research on mirror therapy, recent practices of mirror therapy have shifted from the original movement-based therapy, which comprised forearm, wrist, and knuckle motions, toward task-oriented therapy; these recent practices also apply task-oriented training methods beyond the conventional, simple movement-based therapy [39].

3. Discussion

Stroke is one of the 10 leading causes of death and one of the three major diseases in South Korea. The number of deaths from stroke is 23,415 per 100,000 people, accounting for 45.8%[40]. Stroke is a neurological condition generated by the discontinuation of blood supply due to the rupture of blood vessels or their blockage by blood clots. This disease impairs brain tissues by blocking the supply of oxygen and nutrients [41]. Its symptoms include motor, sensory, cognitive, emotional, and speech disorders [42]. About 16% to 30% of stroke patients show loss of cognitive functions, such as orientation, attention, memory, language skills, and visuospatial ability, within one year after stroke onset. These disorders cause difficulties in performing independent ADLs, including bathing, traveling, and bowel and bladder control [43][44]. Because most ADLs are linked to upper limb function, the recovery of upper limb function has a significant impact on stroke patients. Multiple studies

assert that upper limb function is restored in the early stages of stroke. However, Taub et al. (1993) stated that some patients recovered their upper limb function until one year after stroke onset [27]. They reported that, although quick recoveries are made in the early stages of rehabilitation, active functional recoveries require more time [21]. Therefore, therapeutic approaches aimed at enhancing upper limb function are important [45].

This study found and compiled papers on Bobath therapy, PNF therapy, Task-oriented movement therapy, CIMT, and Mirror therapy among the upper limb rehabilitation methods of stroke patients posted on Pub-Med since 2000.

The principle of Bobath therapy is to inhibit abnormal types of sensory stimulations in the sensorimotor system's abnormal closed loops, arouse normal sensory stimulations as much as possible, and facilitate the maximum level of normal sensory inputs, thereby preventing the vicious cycle of abnormally closed loops. PNF involves spiral and diagonal mass movement patterns. These patterns are a combination of exercises in the sagittal, coronal, and cross-sectional planes. Specifically, PNF combines flexion and extension in the sagittal plane, pronation and supination in the coronal plane, and rotation in the cross-sectional plane. This combination of functional movements increases muscle activities and spreads them toward the proximal and distal areas. Task-oriented movement therapy assumes that the provision of functional tasks to patients and their active problem-solving are more effective for learning than the repeated training of a single movement. Selective task-oriented training is characterized by its task-oriented approach to motor recovery. It is also based on dynamic system theory, which explains the performance of the tasks and motor recovery that occur in the dynamic interactions between individuals, environments, and tasks that they perform. CIMT is offered to stroke patients to enhance hemiplegic patients' upper limb function by overcoming the learned nonuse that occurs in the acute stage after stroke onset and inducing changes in the cerebral cortex. CIMT, which constrains the unaffected side, increases the use of the affected side through continuous and repeated practices of functional arm movements. Recent studies explain this therapy with changes in movement patterns, which are explained through kinetic analyses, and local terminal sprouting or functional synaptic reorganization achieved by stimulating the undamaged cortical circuit and the sensory cortex adjacent to the damaged area. Lastly contradicting the basic concept that sensorimotor training is effective for motor skills, mirror therapy is based on the facilitation of the mirror neuron system and induces improvements in the affected side's movements by providing visual information. Mirror therapy focuses on the fact that visual stimulations are effective for improving motor skills.

4. Conclusion

In the present study, various treatment methods were introduced as stroke interventions to improve upper limb function. They included the Bobath therapy, PNF, task-oriented training, CIMT, and mirror therapy. It is difficult to state that certain evaluation or treatment methods are superior to others. Nevertheless, the flexible applications of the various treatment methods presented by this study to suit varied circumstances will induce effective treatments for the recovery of stroke patients' overall physical functions, thereby ultimately enhancing their upper limb function.

Acknowledgments

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